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Scaffolding expository history text reading: Effects on adolescents' comprehension, self-regulation, and motivation

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ABSTRACT

Reading comprehension is an important predictor for academic success, yet many adolescents in secondary education face difficulties when reading their textbooks. In this quasi-experimental study, we developed a digital learning environment to scaffold students' expository text reading in seventh-grade history classrooms. Students in the experimental condition could use hints comprised of cognitive and metacognitive reading strategy instruction, whereas students in the control condition received no additional support. A comparison of posttest comprehension between conditions showed no significant differences. However, students in the experimental condition who accessed hints during history text reading performed significantly better on the posttest than students who did not use hints at all. We found no differences between conditions regarding students' self-regulated learning or motivation, but students' awareness of problem-solving reading strategies significantly increased in the experimental condition. Finally, a comparison of students with different reading levels showed that below-average readers benefitted most from digital reading practice.

1. Introduction

Reading comprehension is an important prerequisite for learning, particularly in history classes given the abundant use of broad expository texts (Mastropieri, Scruggs, & Graetz, 2003). Reading requires the application of both topic knowledge and domain knowledge (i.e., knowledge about reading strategies), which continually develop after the transition from primary to secondary education (Alexander, 2005). Despite extensive research on reading comprehension in primary education, relatively little is known about reading in secondary education (Barnes, 2015). Most studies focus on reading challenges for struggling adolescent students (Faggella-Luby, Graner, Deshler, & Drew, 2012; Mastropieri et al., 2003; Ness, 2016; Ramsay, Sperling, & Dornisch, 2010). However, all students need to learn how to correctly apply reading comprehension strategies, preferably using relevant and domain-specific content (Lan, Lo, & Hsu, 2014; McKeown, Beck, & Blake, 2009; Shanahan & Shanahan, 2008).

1.1. Comprehending expository history texts

Most history textbooks in secondary education contain fact-dense texts written in expository prose, with difficult vocabulary and obscure internal references (Mastropieri et al., 2003; Ramsay et al., 2010; Swanson et al., 2016). This expository format contrasts the narrative texts that are more common in primary education or language art classes, which makes it difficult for young secondary students to adapt to it (Fry & Gosky, 2007). Therefore, it is important to provide adolescent readers with adequate generic and domain-specific reading strategy instruction.

A case in point is research by Vaughn et al. (2013), that showed that eighth-grade students performed significantly better on content acquisition and reading comprehension when they were provided with specific reading strategy instruction during expository text reading, such as guiding questions for the text. A replication study yielded similar results (Vaughn et al., 2015). Other types of reading strategy instruction based on text content, such as elaborative interrogation or identifying and generating main ideas, have also proved effective for expository text comprehension in history classrooms (McKeown et al., 2009; Ramsay et al., 2010). To comprehend history texts, students need to know how and when to apply relevant reading strategies.

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1.2. Reading and self-regulated learning (SRL)

In general, learners are self-regulated to the degree that they are metacognitively, motivationally and behaviourally active participants in their own learning process. Self-regulated learners can apply learning strategies and adapt their learning behaviour when confronted with problems (Zimmerman, 2008). In line with this definition, self-regulated learning (SRL) is an important skill in the process of reading and comprehending texts (Artelt, Schiefele, & Schneider, 2001; Zimmerman, 2008). When students study their textbooks, they have to regulate their own learning, which includes that they decide which reading strategies they apply from the set of strategies they have at their disposal. According to Mokhtari and Reichard (2002), "awareness *and* monitoring of one's comprehension processes are critically important aspects of skilled reading" (p. 249, italics in the original). In fact, Mason (2013) showed that explicit reading strategy instruction combined with students' self-regulated learning before, while, and after reading has positive effects on students' performance. This three-step approach relates to the SRL model by Zimmerman (2000) and Zimmerman and Moylan (2009).

The cyclical model of SRL by Zimmerman (2000) and Zimmerman and Moylan (2009) is widely used in educational research (Panadero, 2017). It distinguishes three phases in student learning: the forethought phase, the performance phase, and the self-reflection phase. In line with this model, students can self-regulate their reading process by applying reading strategies before, during, and after reading. During the forethought phase, students might set goals for reading, determine the value of the reading task, or indicate the perceived difficulty of the task. During the performance phase, students might monitor their own reading, apply reading strategies, or seek help. During the self-reflection phase, students can evaluate their own reading process in various ways and decide to proceed to a new forethought phase. Each phase encompasses both metacognitive and motivational processes. Recent research on SRL and reading often includes motivational and affective aspects of learning to explore the complex learning processes of adolescent students (Guthrie, Klauda, & Ho, 2013; van Steensel, van der Sande, & Bramer, 2016).

1.3. Reading and student motivation

Since motivation is related to both performance and SRL, it is also essential to consider students' motivation in reading research (Guthrie et al., 2013; Schiefele, Schaffner, Möller, & Wigfield, 2012; Schunk & Zimmerman, 2008; Winne & Hadwin, 2008; Zimmerman, 2011). For example, students' intrinsic goal orientation is an important element of self-regulation: without a clear goal, it is difficult to apply adequate learning strategies (Pintrich, 2000). In addition, students need to recognise the value of a reading task or decrease the perceived difficulty of a reading task (i.e., increase their self-efficacy beliefs) to be motivated to read texts (Guthrie et al., 2013; Pajares, 2008). Students' intrinsic motivation can be increased by stimulating feelings of competence, relatedness, and autonomy (Guthrie et al., 2013; Ryan & Deci, 2000). For example, students' feelings of autonomy are stimulated when they are able to decide which tasks to perform with regard to reading texts. Instruction on SRL strategies can also enhance students' motivation. A study by Zepeda, Richey, Ronevich, and Nokes-Malach (2015) revealed that students who received metacognitive instruction and training showed significantly higher levels of task value, self-efficacy, and mastery-approach goals.

1.4. Struggling readers

Since SRL and motivation contribute to text comprehension, it can be argued that struggling readers—who have difficulties applying relevant strategies when reading expository texts—will benefit most from practice in reading combined with instructional support. In fact, Swanson et al. (2016) showed that struggling readers who daily received specific reading strategy instruction significantly improved on measures of knowledge acquisition, content reading comprehension, and vocabulary recall when compared with struggling students in a business-as-usual condition. Welie, Schoonen, Kuiken, and Van den Bergh (2017) discovered that eighth-grade students' knowledge of connectives (i.e., words that signal coherence in a text, like 'because' or 'therefore') was associated with expository text comprehension and metacognitive knowledge. More specifically, students with more metacognitive knowledge showed a stronger relationship between knowledge of connectives and text comprehension, indicating that students with less knowledge of connectives might benefit from metacognitive instruction to better comprehend expository texts.

1.5. Cognitive and metacognitive scaffolding

There are various ways to support students' text comprehension, SRL, and motivation. Strategy instruction is often used to enhance students' knowledge about which actions might improve their reading. A recent meta-analysis on the effectiveness of reading strategy interventions in whole classrooms showed a small but significant effect of reading strategy interventions on researcher developed-comprehension tests (Cohen's $d = 0.43$); the effect sizes were largest for students in grades 6–8 (Okkinga et al., 2018). With regard to strategy knowledge and strategy use, the authors found small effects (Cohen's $d = 0.37$ and 0.36, respectively); in terms of strategic ability, larger effect sizes were obtained for low-achieving students. The authors conclude that "both knowledge about the different strategies and students' awareness of the type of strategies that are taught can be increased by the reading strategy interventions" (Okkinga et al., 2018, p. 1230).

In their meta-analysis of the effectiveness of learning strategy instruction on academic performance, Donker, de Boer, Kostons, Dignath-van Ewijk, and Van der Werf (2014) make a distinction between cognitive and metacognitive strategies. Cognitive strategies refer to domain or task-specific information; metacognitive strategies are higher-order strategies that regulate students' cognition, such as planning, monitoring, and evaluating. Although a small effect was found for reading comprehension (Hedges' $g = 0.36$), metacognitive knowledge significantly improved student performance. Moreover, Askell-Williams, Lawson, and Skrzypiec (2012) concluded from an extensive inventory with 1388 students that there was room for improvement in early adolescent students' cognitive and metacognitive strategy use. Scaffolding strategy use with learning protocols raised students' levels of strategy knowledge, although this finding was slightly limited. Lastly, an experimental study by Souvignier and Mokhlesgerami (2006) showed that a combination of cognitive, metacognitive, and motivational support is most effective for stimulating students' (long-term) reading comprehension.

Strategy instruction or support can be provided in the form of scaffolds, which contain strategy instruction or guidelines for answering questions. Scaffolds can be defined as "tools, strategies and guides to support students in regulating their learning" (Lajoie, 2005, p. 547), and can include cognitive, metacognitive or motivational processes. Often these scaffolds provide information about how to complete a specific learning task, without disclosing the correct answer (Aleven & Koedinger, 2002; Devolder, van Braak, & Tondeur, 2012; Lysenko & Abrami, 2014; McNamara, 2007). Scaffolds can differ in terms of their function, type of delivery, and the tool or mechanism by which they are presented. A typical scaffold is the prompt or 'hint', which is viewed as a strategy activator (Berthold, Nückles, & Renkl, 2007).

Berthold et al. (2007) provided undergraduate students with either cognitive prompts, metacognitive prompts, a mixture of cognitive and metacognitive prompts, or no prompts at all while writing a learning protocol. They found that participants who received cognitive or mixed prompts performed significantly better on learning outcomes, and

showed significantly more cognitive learning strategies than students who received metacognitive or no prompts. Additionally, students who received prompts (in either way) showed significantly more metacognitive strategy use compared to students who received no prompts. Therefore, they argued that the provision of strategy prompts leads to more cognitive and metacognitive strategy use in students' learning activities.

1.6. Reading in a digital environment

Over the past decades, the possibilities of instructional technology expanded research on the effects of digital learning environments (DLEs) on students' academic performance (Zheng, 2016). With regard to reading comprehension, it has been shown that both instruction and support in DLEs positively affects students' reading comprehension (Cheung & Slavin, 2012; Lan et al., 2014; Lysenko & Abrami, 2014; Moran, Ferdig, Pearson, Wardrop, & Blomeyer, 2008). DLEs enhance students' autonomy and provide individual flexibility and support. Devolder et al. (2012) concluded from their systematic review on scaffolding in computer-based learning environments that digital hints appear to be effective scaffolds, especially as support to stimulate the use of learning strategies. For example, hints can improve students' effort regulation by suggesting what actions to perform when confronted with difficulties while reading texts.

Strategy instruction and SRL supports are established predictors of reading performance. However, many existing studies that use digital or computer-supported environments mainly investigate the effects of support in primary or higher education, even though reading comprehension is equally essential for secondary education (Cheung & Slavin, 2012; Zheng, 2016). Moreover, many studies do not investigate the combined effects of cognitive and metacognitive instruction or scaffolds (Devolder et al., 2012; Lan et al., 2014). Finally, a recent systematic review by Ter Beek, Brummer, Donker, and Opdenakker (2018) showed that hardly any research has been conducted in the field of computer-supported expository text reading in secondary education. Therefore, the current study focuses on the combined use of cognitive and metacognitive support in a digital setting in secondary education, in the specific context of expository history text reading. To our knowledge, this combination of subject-specific, computer-supported research in secondary education has not been conducted in the field of reading comprehension or SRL research so far. By doing this, the current study provides helpful insights for researchers and teachers who wish to integrate supportive educational technology in their lessons.

1.7. Research aims and expectations

The purpose of this study is to determine the effect of cognitive and metacognitive support (i.e., scaffolding through hints) in a digital learning environment on secondary students' expository history text comprehension, SRL, reading strategy awareness, and motivation. Since the use of hints was optional and relied on students' autonomous decisions to use them, the sub-question for each research question focuses on differences between students who accessed hints and students who did not. Additionally, we will analyse if there are different effects for secondary students with below-average, average, and above-average reading levels. We will address the following research questions:

1. What is the effect of the provision and use of cognitive and metacognitive hints on students' history text comprehension?
2. What is the effect of the provision and use of cognitive and metacognitive hints on students' SRL and reading strategy awareness?
3. What is the effect of the provision and use of cognitive and metacognitive hints on students' motivation for history in terms of task value and self-efficacy?
4. What are the effects of the provision and use of cognitive and metacognitive hints on text comprehension, SRL, reading strategy awareness, and motivation for students with different reading levels?

We expect that students who actually use the provided cognitive and metacognitive hints, compared to students who do not use them, will show higher or better (a) text comprehension (cf. Donker et al., 2014), (b) SRL and reading strategy awareness (cf. Berthold et al., 2007; Okkinga et al., 2018), and (c) motivation (cf. Souvignier & Mokhlesgerami, 2006) at posttest. With regard to the students with different reading levels, we expect that students with below-average reading levels will benefit most from this intervention (cf. Okkinga et al., 2018; Swanson et al., 2016), resulting in a larger increase in reading comprehension performance compared to average and above-average readers.

2. Method

2.1. Participants

In the school year of 2016–2017, six seventh-grade classrooms from three Dutch secondary schools participated by using a digital learning environment (DLE) to read expository texts. Initially, the sample consisted of 174 students. There was an equal distribution of boys (n = 88) and girls (n = 86). The average age at the start of the intervention was 12.5 years (SD = 0.42). All classrooms in each school consisted of a mixed educational level of general secondary and pre-university education.[1] The current study did not require submission for ethical approval at the local institutional review board, since it already obtained approval from a governmental review board involved in assessing the grant application. Nevertheless, parents or caretakers of all participating students were informed about the research project via a personal letter and were able to refuse the use of their child's data. We did not receive any such statements.

2.2. Design

This study investigates the effects of a DLE called 'Gazelle'[2] on students' reading of expository texts (ter Beek, Spijkerboer, Brummer, & Opdenakker, 2018). We developed the DLE, to be used in history and geography courses in secondary education, in collaboration with teachers and (non-participating) students. Three secondary schools volunteered to participate in the intervention. All schools were comparable in terms of gender distribution, educational level, denomination, and average final exam results. We randomly assigned two seventh-grade classrooms of each school to a research condition to ensure that all students within a school would be treated equally. This resulted in a quasi-experimental design with two experimental groups (A and B) and one control group (see Table 1).

Students in Experimental group A could consult hints while reading history texts in Gazelle but did not use the program to read geography texts. In Experimental group B, students used Gazelle to read both history and geography texts but were only able to consult hints while reading the geography texts. Originally, we intended to apply a cross-subjects design to test the transfer effects of the available support in one

[1] In Dutch secondary education, many schools mix the educational levels of higher general secondary education (havo) and pre-university education (vwo) in seventh and eighth grade to determine the final educational level of a student at a later stage, based on his or her performance during the early secondary years. The higher general secondary education level grants access to higher vocational education, while pre-university education also grants access to university education.

[2] Gazelle is a Dutch acronym for 'Gemotiveerd en Actief Zelfstandig Lezen', which roughly translates into 'Motivated and Active Independent Reading'. The practice-oriented project report can be consulted via https://www.rug.nl/research/portal/files/77702353/Gazelle_rapport_digitaal.pdf

Table 1
Overview of experimental and control groups.

School	*N* students at school level	*M* final exam result (history)	Group	Hints	Subject(s)	*N* classrooms	*N* students	% girls
A	1364	6.7/10.0	Experimental A	History	History	2	57	52.6
B	1376	6.8/10.0	Experimental B	Geography	History, geography	2	61	52.5
C	1087	6.8/10.0	Control	None	History, geography	2	56	42.9

Note. The average final exam results are based on pre-university students' scores.

subject on the outcomes of the other subject (i.e., geography or history); unfortunately, the geography teachers in Experimental group A decided not to participate in this intervention shortly after the start of the school year. Students in the control group used Gazelle in both subjects but did not receive the opportunity to access hints in either subject (see Table 1). The present study focuses on the effects of using Gazelle on the outcomes for the subject of history. In doing so, Experimental group B functions as a separate condition to test the transfer effects of the provision of hints for geography on the outcomes for history.

2.3. Procedure

Before the intervention started, students completed a reading assessment to determine their initial reading comprehension level. Additionally, they completed a questionnaire to determine students' initial SRL, focusing on metacognitive strategy use and awareness of reading strategies, as well as a questionnaire on students' motivation (i.e., T1; see Fig. 1).

During a six-week intervention, carefully scheduled between two school holidays, students weekly read one expository text for each subject. Teachers integrated the use of Gazelle with their conventional lessons, which lasted about 50 min. For history, the topic of the texts in Gazelle was Ancient Greece, which was in line with the seventh-grade curriculum. We ensured that the texts in Gazelle presented new information to supplement the regular textbooks, whilst taking into account the comparability of the contents and difficulty levels. Each text contained approximately 550 words. Students had to summarise the text directly after reading. Consequently, each student had to answer ten text-related multiple-choice questions. Students could continuously view the text on-screen to rule out the potential influence of memorisation. At the end of each lesson, students assessed their work on a scale of 1 to 10 and reflected on their summary.

Students in the experimental groups were able to consult both cognitive and metacognitive hints while reading texts and answering questions. Cognitive hints appeared alongside the multiple-choice questions and presented strategic information about the literal contents of the text (e.g., “A reason can be found after the appearance of words like *because* or *therefore*”), but they did not provide correct answers. Metacognitive hints presented strategic information about students' regulation of their learning process before, during, and after reading (e.g., “Evaluate your own work by focusing on your progress or concentration, instead of focusing on results”). These hints appeared during reading, summarising, and reflecting. The textual contents of the hints only appeared on screen when students deliberately clicked on a lightbulb-shaped button (see Fig. 2). The hints were static; their contents were equal for all students (Puntambekar & Hubscher, 2005).

Using hints was optional in weeks 2, 3, 4, and 5. During the first and last week of the intervention, none of the students in the different conditions had access to hints. Therefore, the results of week 1 and week 6 allow us to compare students' text comprehension before and after the intervention. We again administered the SRL and motivation questionnaires after the last week of the intervention (i.e., T2).

2.4. Instruments

We adopted three commonly used instruments to measure students' initial reading comprehension, SRL, strategy awareness, and motivation. However, we slightly modified them by translating items from English to Dutch and by adding specific subjects (i.e., ‘in my history class’ or ‘while reading history texts’; ter Beek, Spijkerboer, et al., 2018). Prior to the intervention, we discussed the items in two focus groups with seventh-grade students who did not participate in this study to ensure that the items were understandable for this age group.

2.4.1. Initial reading comprehension

Before the start of the intervention, we assessed students' initial reading comprehension levels by using a recognised Dutch reading instrument (Aarnoutse, 1987). The original instrument consists of four subtests: ‘main ideas’, ‘conjunctures’, ‘synonyms’, and ‘antonyms’. According to Aarnoutse, the subtests for ‘main ideas’ and ‘conjunctures’ relate to higher levels of reading comprehension, such as recognising relationships between parts of the text, whereas ‘synonyms’ and ‘antonyms’ relate to vocabulary knowledge (1987). Therefore, we decided to administer only the ‘conjunctures’ and ‘main ideas’ subtests in this study (see Fig. 3 for examples of subtest questions). We updated the old-fashioned language used in the original instrument and shortened the original ‘main ideas’ subtest from 21 to 8 items due to time constraints and possible overlap with the topics of texts in Gazelle. The original ‘conjunctions’ subtest consisted of 23 items; we excluded two items that substantially lowered the internal consistency. The final 29 items yielded a Cronbach's α of 0.63 and a Guttman's λ_2 of 0.65.

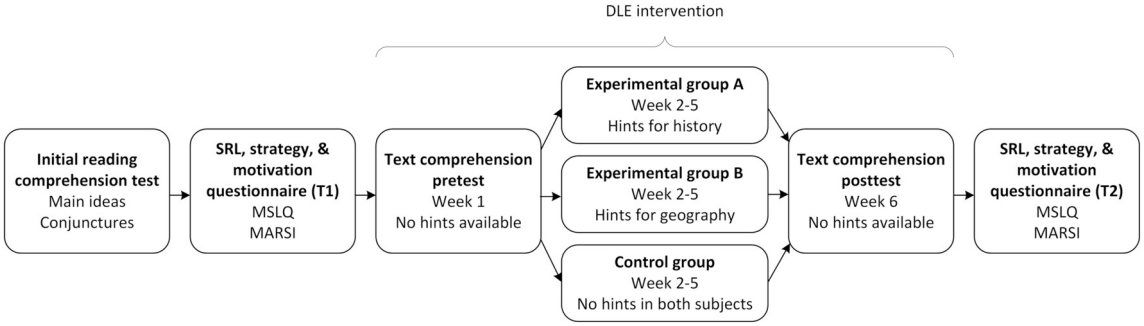

Fig. 1. Timeline for the study and data collection. SRL = self-regulated learning; MSLQ = Motivated Strategies for Learning Questionnaire; MARSI = Metacognitive Awareness of Reading Strategies Inventory.

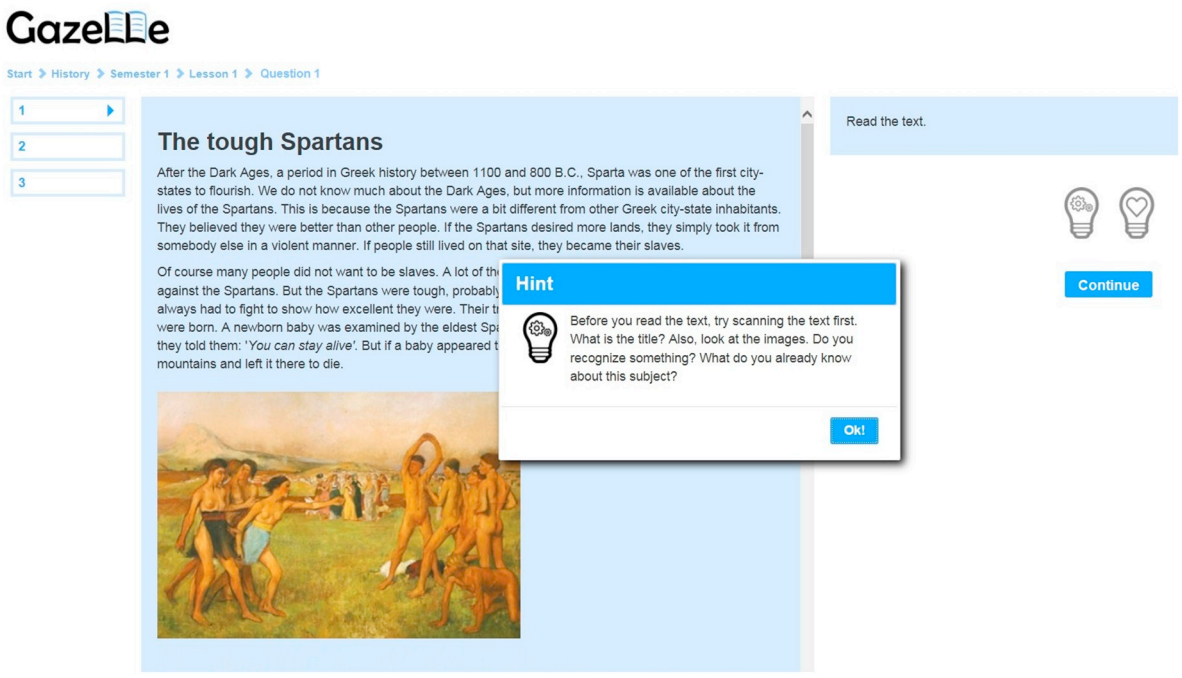

Fig. 2. Screenshot of the Gazelle-program showing the contents of a metacognitive hint.

2.4.2. Self-regulated learning (SRL)

We measured students' SRL using two components of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, García, & McKeachie, 1991). This instrument is widely used to measure students' metacognitive use of learning strategies across different content areas and student populations (García Duncan & McKeachie, 2005). Metacognitive Self-Regulation (MSR; 10 items) focuses on students' metacognitive processes such as planning, monitoring, and regulating (e.g., "I ask myself questions while reading history texts to check whether I understand the information"). Effort Regulation (ER; 3 items) concerns students' control of effort and attention when faced with difficult or tedious tasks (e.g., "I work hard in history class, even if I don't like what I'm doing"), and is related to students' use of learning strategies (Pintrich et al., 1991). In line with de Boer, Hagenbeek, De Waal, Weening, and Admiraal (2013), we reduced the original seven-point Likert-type scale to increase the comprehensibility for the seventh-graders as well as the comparability with other instruments used in this study. Hence, all items were measured on a five-point Likert scale ranging from 1 (*not true at all for me*) to 5 (*absolutely true for me*).

Because this research focuses on reading comprehension strategies, we also administered the Metacognitive Awareness of Reading Strategies Inventory (MARSI; Mokhtari & Reichard, 2002). This inventory provides insight into students' global, problem-solving, and supportive reading strategy awareness. Global reading strategies

Conjunctures

1. The old man fell down ... broke his leg.

Choose the right option:

a) after
b) and
c) but
d) none of the above

Main ideas

1. A female python can lay almost 100 eggs. A ring snake lays only one egg. Many species of snakes leave the eggs that they have laid, but the cobra remains curled up on the eggs until they hatch. Some snakes give birth to their young alive. They carry the unborn young in their body. When they are born, the mother leaves them immediately and lets them take care of themselves. The first thing these young snakes do is shake their skin off.

Which sentence best describes what the whole story is about?

a) Many snakes lay eggs.
b) Hatching snake eggs.
c) How snakes reproduce.
d) Let young snakes take care of themselves.

Fig. 3. Examples of 'conjunctures' and 'main ideas' questions from the initial reading comprehension test (Aarnoutse, 1987; translated from Dutch to English). The correct answers are b and c.

Table 2
Reliability indicators for SRL and motivation subscales (N_{T1} = 172; N_{T2} = 162).

Scale	*N* items	Cronbach's α (T1)	Guttman's λ_2 (T1)	Cronbach's α (T2)	Guttman's λ_2 (T2)
SRL					
MSR	10	0.84	0.84	0.85	0.85
ER	3	0.71	0.72	0.74	0.74
GLOB	13	0.80	0.81	0.89	0.89
PROB	8	0.75	0.76	0.82	0.82
SUP	9	0.77	0.78	0.81	0.82
Motivation					
TV	6	0.78	0.81	0.78	0.80
SE	8	0.87	0.87	0.88	0.88
IGO	4	0.59	0.60	0.59	0.61

Note. SRL = self-regulated learning; MSR = metacognitive self-regulation; ER = effort regulation; GLOB = global reading strategies; PROB = problem-solving strategies; SUP = support reading strategies; TV = task value; SE = self-efficacy; IGO = intrinsic goal orientation.

(GLOB) are related to a global analysis of text (e.g., "I think about what I already know to help me understand what I read for history"). Problem-solving strategies (PROB) aim at what to do when the text becomes too difficult (e.g., "I try to guess the meaning of unknown words or phrases in history texts"). Support reading strategies (SUP) encompass strategies students use to actively support their own reading process (e.g., "I write summaries to reflect on key ideas in the history text"). All items were measured on a five-point Likert scale ranging from 1 (*not true at all for me*) to 5 (*absolutely true for me*). Table 2 shows the reliability for all SRL components.

2.4.3. Motivation

We measured students' motivation with three components of the MSLQ. Task Value (TV; 6 items) refers to the student's evaluation of how interesting or useful a task or course is (e.g., "I am very interested in the contents of my history course"). Self-Efficacy for learning and performance (SE; 8 items) measures the perceived ability to master a task such as reading textbooks (e.g., "I am confident I can understand the basic concepts taught in my history course"). Intrinsic Goal Orientation (IGO; 4 items) provides an indication of student's involvement for reasons such as challenge, curiosity, or mastery (e.g., "For history I prefer texts that really challenge me so I can learn new things"). Similar to the SRL components, all items were measured on a five-point Likert scale ranging from 1 (*not true at all for me*) to 5 (*absolutely true for me*). Table 2 shows the reliability for the motivation components. We report both Cronbach's α and Guttman's λ_2; although Cronbach's α is commonly used in educational research, Guttman's λ_2 is a better reliability estimator according to Drenth and Sijtsma (2005).

The reliability indicators in Table 2 are comparable with those of the original instruments, although the scores for TV and IGO are lower than the original alpha values of 0.90 and 0.74 (Pintrich et al., 1991). Just like Zepeda et al. (2015), we decided not to further analyse the results for IGO due to the low reliability.

2.4.4. Text comprehension

During the six-week intervention, students weekly answered ten text-related multiple-choice questions. These questions covered relevant reading skills, such as recognising causal relationships (e.g., "How did the Spartans become such good soldiers?") or explaining historical events (e.g., "Explain why the 300 Spartan soldiers went into battle against 10,000 Persians"). All multiple-choice questions of weeks 1 and 6 were comparable in terms of addressing different skills and covering text contents. Students received one point per correct answer, which led to a maximum score of 10 points. Consequently, we used the results on the multiple-choice questions of weeks 1 and 6 as pretest and posttest measures of students' text comprehension.

2.4.5. Hint use

Log-files in Gazelle registered whether students accessed cognitive or metacognitive hints. In weeks 2 through 5, students could access 16 metacognitive hints before, during, and after reading the text and 80 cognitive hints while answering the multiple-choice questions.

2.5. Analyses

To calculate initial reading comprehension, we computed overall mean scores for the combined 'main ideas' and 'conjunctures' subtests. For SRL and motivation, we computed a mean score for each subscale (i.e., MSR, ER, GLOB, PROB, SUP, TV, and SE) if a student answered at least 80% of the scale's items. We calculated sum scores for the multiple-choice questions in week 1 (pretest) and week 6 (posttest). Hint use was determined for each hint separately as a dichotomous variable (no use = 0, use = 1) and subsequently aggregated.

We used variance analysis with General Linear Models (GLM), paired samples *t*-tests, and post hoc Bonferroni tests to answer the research questions. All tests were performed as two-sided tests. The use of the terms 'ANOVA' and 'ANCOVA' in the Results section refer to the variance analyses with GLM. We report effect sizes using partial eta squared, or partial η^2, since this is a commonly used measure of effect sizes in the educational research literature (Richardson, 2011). Partial eta squared refers to the magnitude of the effect of the intervention controlled for the covariates, which gives a more realistic impression of the effect of the intervention. We consider effect sizes as small when partial $\eta^2 < 0.06$, medium when $0.06 <$ partial $\eta^2 < 0.14$, and large when partial $\eta^2 > 0.14$ (cf. Cohen, 1988; Zepeda et al., 2015). When comparing two groups, we also report Cohen's *d* as an effect size, for which a value of 0.2 can be considered a small effect, 0.5 a medium effect, and 0.8 a large effect.

2.5.1. Missing values

For the initial reading comprehension test, we excluded the results of six students because they did not execute the test seriously (e.g., their time spent on the test was two standard deviations below average or severe negative outliers). Data were missing for two students who were sick on the day of administration. Therefore, the final sample for the initial reading comprehension test was 166 students. For the SRL and motivation questionnaires on T1, data for two students were missing. Therefore, the final sample on T1 is 172. On T2, data were missing for 12 students (7% of the total sample) due to sickness or classroom migrations. In total, 160 students completed both questionnaires (i.e., T1 and T2). With regard to text comprehension, all students completed the multiple-choice questions for week 1, but data of three students were missing for week 6. Therefore, 171 students completed both the multiple-choice pre and posttest in Gazelle. The number of students who completed all measurements was 155 (89% of the initial sample).

2.5.2. Independent groups and subgroups

To answer RQs 1, 2, and 3, we compared students between and within the three different research conditions: Experimental group A, Experimental group B, and the control group. To analyse of the use of hints, we focused solely on the students in Experimental group A, who were provided with hints while reading history texts (N = 57). To examine whether the intervention affected students within the conditions differently, we made a distinction between students based on their results on the initial comprehension test (N = 166; M = 22.56, SD = 3.46). We categorised students who scored below one standard deviation (i.e., 19 points or lower) as 'below-average readers' (n = 31); students who scored 20 up to 25 points were categorised as 'average readers' (n = 102); and students who scored above one standard deviation (i.e., 26 points or higher) as 'above-average readers' (n = 33). We use this distinction to answer RQ4.

3. Results

3.1. Preliminary analyses

3.1.1. Initial reading comprehension

An ANOVA revealed a significant difference between the three research conditions in initial reading comprehension performance, $F(2, 163) = 11.66$, $p < .001$, partial $\eta^2 = 0.13$, with the initial comprehension in Experimental group B ($M = 20.90$, $SD = 3.57$) being lower than Experimental group A ($M = 23.54$, $SD = 3.06$) and the control group ($M = 23.37$, $SD = 3.09$). The initial reading comprehension test was only used to distinguish below-average, average, and above-average readers ($N = 166$).

3.1.2. Text comprehension at pretest

An ANOVA revealed a significant difference between the three research conditions for comprehension performance at the pretest, $F(2, 171) = 3.13$, $p = .046$, partial $\eta^2 = 0.04$, with a lower score for the control group ($M = 6.77$, $SD = 1.84$) compared to Experimental groups A and B ($M = 7.61$, $SD = 1.70$; $M = 7.16$, $SD = 1.85$, respectively). Bonferroni post hoc tests showed that the control group performed significantly lower than Experimental group A, $p = .040$. Because the pretest was more similar to the posttest than the initial reading comprehension test, and the three research conditions significantly differed from each other, we decided to include the pretest performance as a covariate in further analyses ($N = 171$).

3.1.3. Hint use

Out of the 57 students in Experimental group A, 30 students used a cognitive or metacognitive hint at least once (i.e., the 'hint users'); 27 students did not use any hints (i.e., the 'non-hint users'). These 30 students used a total of 156 cognitive hints and 30 metacognitive hints; an average of 3.26 hints per student (see Table 3). Out of these 30 students, nine students only used a single hint. The average number of hints used decreased throughout the intervention. Since students' decision to use hints (or not) can be affected by a variety of factors, we approached the analysis in two ways. The first approach stresses students' deliberate decision and, thus, if students opened at least one of the available hints during the entire intervention they were categorised as 'hint users' ($n = 30$) and compared to non-hint users ($n = 27$). However, since accessing only a single hint could also have been caused by curiosity rather than an actual need for help, the second approach also stresses the use of more than one hint, and thus, we categorised the students as those who accessed multiple hints ($n = 21$), a single hint ($n = 9$), and no hints ($n = 27$). Students who accessed metacognitive hints always accessed cognitive hints as well; therefore, we were not able to compare different types of hint users with regard to the contents of the hints.

3.1.4. Difficulty of multiple-choice questions in weeks 1 and 6

Analysis of the mean scores on each of the ten multiple-choice questions showed that week 6 included relatively more difficult questions than week 1, leading to an decline in performance ($M = 3.35$, $SD = 1.62$). We corrected the scores of week 6 using an equation procedure similar to a method frequently used in Dutch national final exams (College voor Toetsen en Examens & Cito, 2011). Based on the cumulative frequencies of the scores on the pre and posttest, we concluded that we had to add 3.2 points to the posttest sum scores to provide a more representative impression of students' performance. The corrected posttest sum scores were used in all analyses.

Table 3
Average number of hints used per student in experimental group A (N = 57).

Hints	Week 2 *M* (*SD*)	Week 3 *M* (*SD*)	Week 4 *M* (*SD*)	Week 5 *M* (*SD*)	Total *M* (*SD*)
Cognitive	1.72 (2.72)	0.53 (1.30)	0.26 (0.96)	0.23 (0.73)	2.74 (4.39)
Metacognitive	0.56 (0.82)	0.30 (0.65)	0.14 (0.44)	0.09 (0.29)	0.53 (1.18)
Total	2.28 (3.31)	0.82 (1.75)	0.40 (1.24)	0.32 (0.81)	3.26 (5.21)

Table 4
Mean pre and posttest scores on reading comprehension by group/subgroup (N = 171).

Group/*subgroup*		Pretest	Posttest
	n	*M* (*SD*)	*M* (*SD*)
Experimental A	57	7.61 (1.70)	6.31 (1.43) ***
Experimental B	60	7.17 (1.87)	6.38 (1.41) **
Control	54	6.78 (1.87)	5.88 (1.55) **
Within Experimental A:			
Hint users (1 or more)	30	7.60 (1.81)	6.68 (1.39) *
Non-hint users (0 hints)	27	7.63 (1.60)	5.90 (1.39) ***
Multiple-hint users (2 >)	21	7.86 (1.59)	6.71 (1.45) *
Single-hint users (1 hint)	9	7.00 (2.24)	6.60 (1.33)
Non-hint users (0 hints)	27	7.63 (1.60)	5.90 (1.39) ***

Note. The significance represents within-group comparisons, $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$. The italicised subgroups refer to the comparisons between two different operationalisations of hint users.

3.2. Effects on text comprehension (RQ1)

3.2.1. Experimental vs. control conditions

An ANCOVA with pretest comprehension performance as a covariate showed no significant differences in posttest comprehension performance between the three research conditions, $F(2, 167) = 1.39$, $p = .252$, partial $\eta^2 = 0.02$. Paired samples *t*-tests showed that the posttest comprehension performance of all groups significantly declined (see Table 4).

3.2.2. Hint use

With 'hint use' operationalised as a deliberate decision to use at least one hint during the intervention, a comparison of hint users and non-hint users showed no significant difference in comprehension performance on the pretest, $F(1, 55) < 0.01$, $p = .948$, partial $\eta^2 < 0.01$, indicating that the hint users were not mainly low or high performers. However, there was a significant difference in posttest performance in favour of the hint users ($M = 6.68$, $SD = 1.39$) versus the non-hint users ($M = 5.90$, $SD = 1.39$), $F(1, 55) = 4.46$, $p = .039$, partial $\eta^2 = 0.08$, $d = 0.56$. Additionally, hint users descriptively performed better on the posttest than students in Experimental group B and the control group (see Table 4).

Similar analyses with the operationalisation of 'hint use' including the use of multiple hints (i.e., comparing multiple hints, a single hint, or no hints) also showed no significant differences in pretest performance. There was a small difference in posttest performance in favour of the multiple-hint users ($M = 6.71$, $SD = 1.45$) and the single-hint users ($M = 6.60$, $SD = 1.33$) versus the non-hint users ($M = 5.90$, $SD = 1.39$); however, these differences were not significant, $F(1, 54) = 2.22$, $p = .119$, partial $\eta^2 = 0.08$. The decline in performance was significant for all students with 'hint use' operationalised as a deliberate decision, comparing 'hint users' and 'non-hint users'. However, when operationalising 'hint use' as also including the use of more than one hint—comparing multiple hints, a single hint, or no hints—the decline was not significant for the single-hint users (see Table 4).

3.3. Effects on SRL (RQ2)

3.3.1. Experimental vs. control conditions

A comparison between the three research conditions yielded no significant differences on all SRL scales (i.e., MSR, ER, GLOB, PROB, and SUP) at T1 and T2. However, when comparing T1 with T2, the

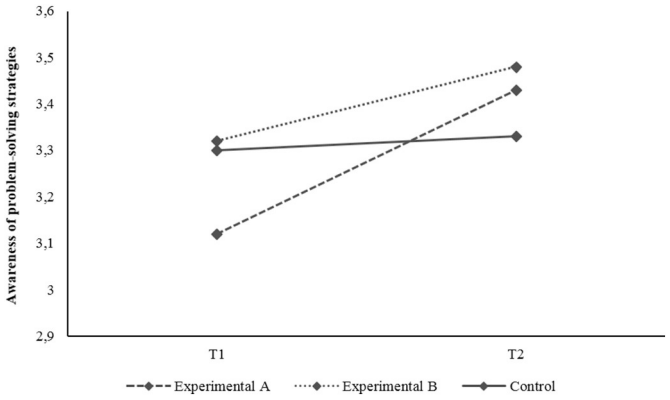

Fig. 4. Mean problem-solving strategies at T1 and T2 by group for the subject of history (cf. ter Beek, Spijkerboer, et al., 2018).

PROB scale increased for all conditions, but this increase was only significant for Experimental groups A and B (see Fig. 4 and Table 5). GLOB and SUP significantly decreased in the control group ($p < .001$ and $p = .003$, respectively); SUP also significantly decreased in Experimental group B ($p = .012$).

3.3.2. Hint use

With 'hint use' operationalised as a deliberate decision to use at least one hint during the intervention, ANOVA analyses comparing the SRL scales of hint users and non-hint users yielded no significant differences at T1 and T2. However, paired samples *t*-tests comparing the SRL scales at T1 and T2 showed a significant increase in PROB, $p < .001$, for both hint users and non-hint users. With the operationalisation of 'hint use' also including the use of multiple hints, the analyses also did not yield significant differences between the three groups at T1 and T2. However, both the multiple-hint users and the non-hint users showed a significant increase in PROB, $p = .002$ for multiple-hint users and $p < .001$ for non-hint users. Additionally, single-hint users showed a significant increase in MSR, $p = .012$.

3.4. Effects on motivation (RQ3)

3.4.1. Experimental vs. control conditions

The mean score on TV at T1 was significantly higher for the control group compared to Experimental group A, $F(2, 170) = 4.45$, $p = .013$, partial $\eta^2 = 0.05$. In addition, the mean score on SE at T1 was significantly higher for the control group compared to Experimental group A and B, $F(2, 169) = 9.95$, $p < .001$, partial $\eta^2 = 0.11$. An ANCOVA with the mean scores at T1 as a covariate yielded no significant results between conditions on both motivation scales at T2. When comparing T2 with T1, TV and SE decreased for all groups, but not significantly (see Table 5). Therefore, the provision of hints did not result in significant changes in motivation of all groups.

3.4.2. Hint use

With 'hint use' operationalised as a deliberate decision to use at least one hint during the intervention, ANOVA analyses comparing hint users and non-hint users on TV and SE showed no significant differences at T1 and T2. This also indicates that students' motivation did not influence their hint use. Additionally, *t*-tests comparing T1 with T2 for hint users and non-hint users showed no significant differences. With the operationalisation of 'hint use' also including the use of multiple hints, we also found no significant differences for TV and SE.

3.5. Students with different reading levels (RQ4)

3.5.1. Text comprehension

There was a significant difference between the pretest comprehension performance of below-average readers, average readers, and above-average readers, $F(2, 163) = 4.58$, $p = .012$, partial $\eta^2 = 0.05$. Bonferroni post hoc tests showed that above-average readers performed significantly better than below-average and average readers, $p = .013$ and $p = .043$, respectively. An ANCOVA with pretest comprehension performance as a covariate and Bonferroni post hoc testing showed no significant difference in posttest comprehension performance for the three reader types. Paired samples *t*-tests showed that the performance of average and above-average readers significantly declined, $p < .001$. However, the decrease was not significant for below-average readers, $p = .112$ (see Table 6). Below-average readers even outperformed average readers on the posttest.

3.5.2. Self-regulated learning (SRL)

There were no significant differences between the three reader types at T1 for all SRL scales, indicating that although their initial comprehension performance varied, their SRL did not. Furthermore, there were no significant differences between the reader types at T2. However, paired samples *t*-tests showed that there was a significant increase on MSR and PROB for average readers, $p = .002$ and $p < .001$, respectively. There were no changes in any of the SRL scales for below-average readers. There was a significant decrease in SUP for above-average readers, $p = .037$ (see Table 7).

3.5.3. Motivation

A comparison of the three reader types indicated no significant differences in motivation at T1 and T2. Paired samples *t*-tests showed that SE significantly decreased for below-average readers, $p = .043$.

Table 5
Mean T1 and T2 scores on SRL and motivation scales by condition (N = 160).

	Experimental group A ($n = 56$)		Experimental group B ($n = 58$)		Control group ($n = 46$)	
Scale	*M* (*SD*) T1	*M* (*SD*) T2	*M* (*SD*) T1	*M* (*SD*) T2	*M* (*SD*) T1	*M* (*SD*) T2
SRL						
MSR	3.06 (0.50)	3.20 (0.51)	3.09 (0.51)	3.16 (0.51)	3.17 (0.80)	3.12 (0.72)
ER	3.58 (0.62)	3.58 (0.61)	3.55 (0.68)	3.61 (0.61)	3.91 (0.64)	3.76 (0.74)
GLOB	3.27 (0.48)	3.25 (0.47)	3.23 (0.46)	3.32 (0.50)	3.46 (0.66)	3.14 (0.73) ***
PROB	3.12 (0.51)	3.43 (0.49) ***	3.32 (0.47)	3.48 (0.52) **	3.30 (0.74)	3.33 (0.72)
SUP	3.12 (0.52)	3.02 (0.54)	3.06 (0.49)	3.24 (0.54) *	3.30 (0.71)	3.04 (0.76) **
Motivation						
TV	3.26 (0.69)	3.15 (0.57)	3.34 (0.54)	3.29 (0.55)	3.67 (0.57)	3.60 (0.71)
SE	3.53 (0.46)	3.52 (0.53)	3.40 (0.59)	3.37 (0.46)	3.84 (0.43)	3.81 (0.48)

Note. SRL = self-regulated learning; MSR = metacognitive self-regulation; ER = effort regulation; GLOB = global reading strategies; PROB = problem-solving strategies; SUP = support reading strategies; TV = task value; SE = self-efficacy. The significance represents within-group comparisons of T1 and T2, *$p < .05$. **$p < .01$. ***$p < .001$.

Table 6
Mean pre and posttest scores on reading comprehension by reader type (N = 164).

Type		Pretest	Posttest
	n	*M* (*SD*)	*M* (*SD*)
Below-average readers	30	6.87 (1.81)	6.23 (1.50)
Average readers	101	7.25 (1.65)	6.07 (1.43) ***
Above-average readers	33	8.06 (1.52)	6.61 (1.44) ***

Note. The significance represents within-group comparisons, *$p < .05$. **$p < .01$. ***$p < .001$.

There were no significant differences in motivation for average readers. However, TV decreased significantly for above-average readers, $p = .011$ (see Table 7).

3.5.4. Interaction effects

To test whether the *provision* of hints during expository history text reading had differential effects on comprehension performance for the three reader types, we tested for possible interaction effects. Levene's Test indicated there was no violation of the assumption of equal error variances, $F(8, 155) = 0.82$, $p = .588$. An ANCOVA with reader type and experimental condition as predictors, experimental condition × reader type as the interaction term, and pretest performance as a covariate yielded no significant difference in posttest performance between the conditions for any of the three reader types, $F(4, 154) = 0.44$, $p = .777$, partial $\eta^2 = 0.01$. Similar analyses for the SRL and motivation scales also yielded no significant results.

3.5.5. Hint use

To test whether the deliberate use of hints (i.e., using at least one hint) during expository history text reading had differential effects on comprehension performance for the three reader types, the interaction effects between reader type and the hint users vs. non-hint users within Experimental group A were investigated. Levene's Test indicated there was no violation of the assumption of equal error variances, $F(5, 50) = 1.22$, $p = .312$. An ANCOVA with reader type and hint use as predictors, hint use × reader type as the interaction term, and pretest performance as a covariate yielded no significant difference in posttest performance between hint users and non-hint users for any of the three reader types, $F(2, 49) = 0.51$, $p = .606$, partial $\eta^2 = 0.02$. Similar analyses for the SRL and motivation scales also yielded no significant results. Finally, similar analyses with 'hint use' operationalised as also including the use of multiple hints did not yield significant differences in posttest performance, SRL, or motivation for any of the three reader types.

4. Discussion

Research has shown that instructional support in DLEs can have a positive effect on students' reading comprehension and academic performance (Cheung & Slavin, 2012; Lysenko & Abrami, 2014; Moran et al., 2008). This study added elements of autonomy and self-regulation to a DLE: students were able to decide whether and when to use cognitive and metacognitive support during history text reading. As such, the present study also addressed the possible effects of hint use on students' SRL and motivation.

4.1. Summary of findings

Regarding text comprehension (i.e., RQ1), results showed no significant differences in posttest comprehension performance between the three conditions. A possible explanation might be that, in general, students in Experimental group A hardly used hints. In essence, students who did not use hints were identical to students in the control group, making it hard to compare them. However, we did find a significant difference in posttest comprehension performance in favour of the operationalisation of 'hint users' as students who deliberately used one or more hints during the intervention compared to students who did not use hints. Analyses in which 'hint users' were operationalised otherwise—as students who accessed *single* or *multiple* hints—did not yield any significant results, but effect sizes (partial $\eta^2 = 0.08$) were similar for both operationalisations of hint users. Thus, our expectation regarding hint users outperforming non-hint users was partially confirmed. We will discuss and reflect on the findings with regard to 'hint users' in the following section using the operationalisation of students who used one or more hints unless we explicitly state this otherwise.

The finding that hint users outperformed non-hint users (albeit only with a specific operationalisation of these groups) is in line with earlier research studies, in which students in the experimental conditions who were provided with strategy instruction outperformed students who did not receive such instruction (Berthold et al., 2007; Mason, 2013; McKeown et al., 2009; Ramsay et al., 2010; Souvignier & Mokhlesgerami, 2006; Vaughn et al., 2013, 2015; Zepeda et al., 2015). However, implications of our findings with regard to performance must be considered carefully, given the fact that performance scores declined significantly in all groups throughout the intervention. This probably has more to do with students' decline in motivation than with the provision and use of hints.

There were no significant differences between conditions or between hint users with regard to SRL and strategy awareness (i.e., RQ2); this expectation was not met. Nevertheless, students in Experimental group A and B, who were provided with hints during expository history or geography text reading, significantly increased their levels of problem-solving strategy awareness, indicating that this practice might be

Table 7
Mean T1 and T2 scores on SRL and motivation scales by reader type (N = 155).

	Below-average readers (*n* = 30)		Average readers (*n* = 93)		Above-average readers (*n* = 32)	
Scale	*M* (*SD*) T1	*M* (*SD*) T2	*M* (*SD*) T1	*M* (*SD*) T2	*M* (*SD*) T1	*M* (*SD*) T2
SRL						
MSR	3.20 (0.60)	3.13 (0.53)	3.01 (0.57)	3.19 (0.59) **	3.20 (0.64)	3.09 (0.59)
ER	3.80 (0.61)	3.67 (0.60)	3.59 (0.71)	3.61 (0.69)	3.80 (0.59)	3.70 (0.62)
GLOB	3.29 (0.59)	3.29 (0.55)	3.29 (0.48)	3.23 (0.55)	3.35 (0.64)	3.18 (0.64)
PROB	3.28 (0.56)	3.37 (0.53)	3.18 (0.56)	3.44 (0.59) ***	3.30 (0.65)	3.39 (0.61)
SUP	3.07 (0.65)	3.19 (0.59)	3.13 (0.50)	3.11 (0.61)	3.21 (0.65)	2.98 (0.67) *
Motivation						
TV	3.51 (0.58)	3.40 (0.53)	3.33 (0.62)	3.32 (0.60)	3.50 (0.69)	3.26 (0.82) *
SE	3.56 (0.53)	3.39 (0.59) *	3.53 (0.56)	3.58 (0.50)	3.72 (0.45)	3.63 (0.53)

Note. SRL = self-regulated learning; MSR = metacognitive self-regulation; ER = effort regulation; GLOB = global reading strategies; PROB = problem-solving strategies; SUP = support reading strategies; TV = task value; SE = self-efficacy. The significance represents within-group comparisons of T1 and T2, *$p < .05$. **$p < .01$. ***$p < .001$.

useful for students' SRL—irrespective of whether students actually use the hints. While reading expository texts, students in the experimental groups could decide for each question whether they wanted to use a supportive hint. This option may have stimulated students' problem-solving strategies, since some students preferred to figure out the problem without using the hint; some students even expressed that they considered using hints as 'cheating'. This corresponds with the work of Roll, Baker, Aleven, and Koedinger (2014), who state that avoiding help is sometimes "associated with *better* performance than seeking help on steps for which students have low prior knowledge" (pp. 537–538, italics in the original). In contrast, awareness of global and support reading strategies significantly decreased for the control group, indicating that the lack of support might have had a negative influence on students' overall reading strategy awareness.

Regarding students' motivation (i.e., RQ3), there were no significant differences for the different conditions and hint users; thus, our expectations were not confirmed. Task value and self-efficacy decreased throughout the intervention in all groups, indicating that student motivation for the history course in general diminished over time, albeit not significantly. Teachers also stressed the low motivation levels of their students, since the average time spent on reading texts in the DLE declined in all conditions. The decrease in students' motivation probably influenced students' posttest reading comprehension performance, which was unexpectedly lower than their pretest performance. Unfortunately, empirical research regarding effective digital support on intrinsic reading motivation is scarce, especially in secondary education (Moran et al., 2008; van Steensel et al., 2016). Many existing reading interventions focus on motivation in terms of competence, social aspects, and rewards, whereas only a few address the value of reading (van Steensel et al., 2016). Although research has shown that relatively short, two to four-week interventions yield larger effect sizes in this type of research (cf. Moran et al., 2008), it seems that the repetitive character of our six-week intervention fostered reluctance to work with the DLE, and, consequently, had a negative effect on students' general motivation for history. This relates to the findings of Azevedo, Cromley, and Seibert (2004), who found less stated interest in students when they were scaffolded with domain-specific guiding or hints.

With regard to students with different reading levels (i.e., RQ4), it seems that practising in the DLE had diverse effects. First, there is a discrepancy between reading comprehension and self-efficacy of below-average readers. In contrast to the average and above-average readers, below-average readers' performance did not significantly decline during the intervention; thus, our expectation was partially confirmed. This corresponds to earlier research studies focusing on struggling students or students with learning disabilities in social studies text interventions (Swanson et al., 2014, 2016). Below-average readers even descriptively outperformed average readers on the posttest. However, their self-efficacy beliefs significantly decreased over time. This might be due to the direct feedback on each multiple-choice question: Multiple indications of incorrect answers confronted below-average readers with their lack of reading comprehension, which in turn might have lowered their self-efficacy beliefs. Second, above-average readers' task value and reading comprehension performance declined significantly. Above-average readers possibly felt no need to practise their reading, provoking decreased motivation, metacognitive self-regulation, and effort regulation and in turn leading to lower performance on the posttest.

4.2. Limitations

The main limitation of the present study is students' use of hints in general. We must treat findings for 'hint users' versus 'non-hint users' with caution: out of the 57 students who could use hints during history text reading, only 30 used a hint at least once, and nine students only opened a single hint during the intervention. Given the low number of hints used, we dichotomised the hint use variable, but this precluded the opportunity to analyse hint use more extensively. Moreover, a different operationalisation of hint users (i.e., with three groups) did not yield any significant differences; this is probably related to a power problem due to the low number of students in the single-hint user group. Nevertheless, an interesting finding was the fact that single-hint users' MSR increased significantly throughout the intervention. Paradoxically, the increased self-regulation of these students is probably invoked by *not* using more than a single hint. Therefore, it might be useful to uncover why individual students did or did not use the cognitive and metacognitive hints in more detail.

Although hint users initially did not differ from non-hint users in terms of task value and self-efficacy, it seems likely that intrinsic motivation is related to hint use. Additionally, the students in this study might not have had sufficient metacognitive knowledge or metacognitive skills to decide whether they needed a hint or not. Even if they did use hints, it should not be assumed that they were able to use the strategic information offered by the hint effectively (Aleven & Koedinger, 2000; Azevedo, Moos, Greene, Winters, & Cromley, 2008; de Kock, 2016). Furthermore, it is possible that the provision and use of hints in the DLE increased students' cognitive load, since the hints contained even more text to read (cf. Berthold, Röder, Knörzer, Kessler, & Renkl, 2011; Kirschner, 2002). Future research should also include qualitative research data, such as student interviews or trace data, to be able to explain the findings with regard to students' hint use and strategy awareness in more detail.

Another limitation of this study is the fact that students in Experimental group A only used the DLE for reading history texts, whereas both other groups used it for both history and geography lessons. Unfortunately, the geography teachers of Experimental group A unexpectedly decided not to participate in the intervention. Our current design presupposed the use of the DLE in an ecologically valid context; however, it was also prone to challenges in the case of classroom or teacher attrition. Moreover, students from Experimental group B and the control group, who read texts for both subjects, complained about the density and repetitive character of the DLE. Satiation or boredom with the initially new programme might have resulted in lower motivation, effort regulation, or strategy use.

In the present study, students worked by design independently in the DLE without any help or instruction from their teacher. However, Azevedo et al. (2008) discovered that externally facilitated learning, in which teachers have an active role in guiding students' SRL, leads to higher knowledge gains and more effective metacognitive strategy use by students. This lack of guidance might have resulted in lower and ineffective hint use, which could explain the decline in comprehension performance for hint users. It is probably helpful to train teachers in using the DLE in their classroom context to stimulate the text comprehension, strategy use, and motivation of their students.

A final limitation of this study is that we did not include students' vocabulary and background knowledge in our analyses; two factors that contribute to text comprehension in adolescent readers (Cromley & Azevedo, 2007). By focusing on students' ability to generate correct main ideas and conjunctions, we might have overlooked basic vocabulary skills and knowledge as important prerequisites for comprehending expository history texts. Therefore, the results regarding the reader types (below-average, average, and above-average readers) should be interpreted with caution. Future research on expository text reading should address multiple components of reading comprehension to obtain a more comprehensive picture of what influences students' comprehension performance during reading interventions.

4.3. Practical and scientific implications

Practising expository text comprehension in a DLE, with or without reading strategy support, can improve below-average readers' text comprehension. However, for above-average readers, this practice might be detrimental for their motivation for the subject of history. Therefore, we suggest that teachers carefully consider which students

can benefit from digitally supported reading practice. Moreover, not all students in this study who had the option to use hints also made use of the available support. It should not be expected that using an apparently rich and complex learning environment automatically results in more self-regulated use of hints. Therefore, teachers need to ensure that students consider help seeking as 'normal' and stimulate their students to use the support offered—regardless of the specific DLE used in this research. Teachers should also not assume that all seventh-grade students already possess the necessary self-regulated learning skills for reading expository texts, or that students are fully aware of when and how to apply relevant reading strategies.

This research shows that the use of a DLE with integrated strategy instruction can be beneficial to provide differentiated practice for students who struggle with reading their textbooks. On a scientific level, this research complements the existing knowledge about the use of computer-supported or digital learning in educational practice, whilst also highlighting the possible challenges posed by this type of practical research. In addition, it provides a good example of the impact of methodological decisions on the outcomes, such as the operationalisation of subgroups. Notwithstanding these challenges, it is of continued importance to keep up with the rapid technological innovations of the 21st century by analysing 'what works' in education, and thereby to ensure that the use of technology in the classroom contributes to the development of individual students.

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Declaration of Competing Interest

None.

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